Introduction to SLM and CLIPPING Techniques and its Comparative Analysis to Reduce PAPR in OFDM System

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***Abstract*— In this paper we are going to analyze the two techniques namely CLIPPING and SELECTIVE MAPPING (SLM) which are used to reduce PAPR in OFDM system. Peak to average power ratio (PAPR) of OFDM signal is the main drawback which results in poor data transmission in OFDM system. For a better communication, data rate should be high accompanied by high power efficiency and low Bit error rate (BER). OFDM is the multicarrier modulation technique considered to be a better means of communication due to its orthogonal nature formed between the sub carriers and its cost effectiveness. Due to high PAPR in OFDM signal the power amplifier in the transmitter end will operate in the saturation region because of which there will be in-band distortion and out-band radiation and hence the performance of OFDM system is degraded. To overcome this problem of high PAPR we are introducing the above mentioned two techniques with their comparative analysis.**

***Index Terms*— BER, Clipping, OFDM, PAPR, SLM.**

I. INTRODUCTION

IN digital transmission, Orthogonal Frequency Division Multiplexing (OFDM) is a method which is used to meet the increasing demands for higher data rates in both wireless and wired communication. This method has been employed for Asymmetric Digital Subscriber Line (ADSL), Digital Audio Broadcasting (DAB), and Digital Video Broadcasting (DVB). OFDM is considered as a physical layer for the wireless networking standard HIPERLAN2 and IEEE 802.11a.

OFDM system removes Inter Carrier Interference (ICI) and Inter Symbol Interference (ISI) and it gives good bit error rate performance. It efficiently uses the spectrum by dividing channel into narrow band flat fading sub channels. The PAPR will occur because of constructive interference at certain intervals in an OFDM system. This is the biggest drawback of OFDM system. Due to this there will be poor power efficiency and during the time of transmission through power amplifier, there will be performance degradation. As a result there will be high signal peaks which produces nonlinearity in the system, inter modulation in subcarriers and out of band radiation.

A. Motivation

In today's world the devices that are portable are inevitably present everywhere and portable devices have a finite battery life. So, it becomes very much important to reduce the PAPR allowing for smaller and more efficient high power amplifier which provides long lasting battery life.

PAPR reduction techniques are classified into signal scrambling and signal distortion. In scrambling technique it scrambles the codes to reduce PAPR, such as selective mapping and in distortion method high peak is distorted in OFDM signal using different techniques, such as clipping.

In this paper, we provide a comparison and analysis between selective mapping and clipping. The pros and cons of each method is studied from the simulation results.

B. Contribution

a. To design a low complex scheme based on signal distortion technique.
b. To design efficient scheme based on signal scrambling technique.
c. The computational complexity and system performance for the proposed schemes will be compared and optimum method to reduce the PAPR is proposed.

II. SYSTEM MODEL

A. OFDM Transceiver

OFDM transceiver is a device that consists of both transmitter and receiver which are combined and have a common circuitry.

OFDM system block diagram is shown below. The basic outline of an OFDM system consists of the following components and description.

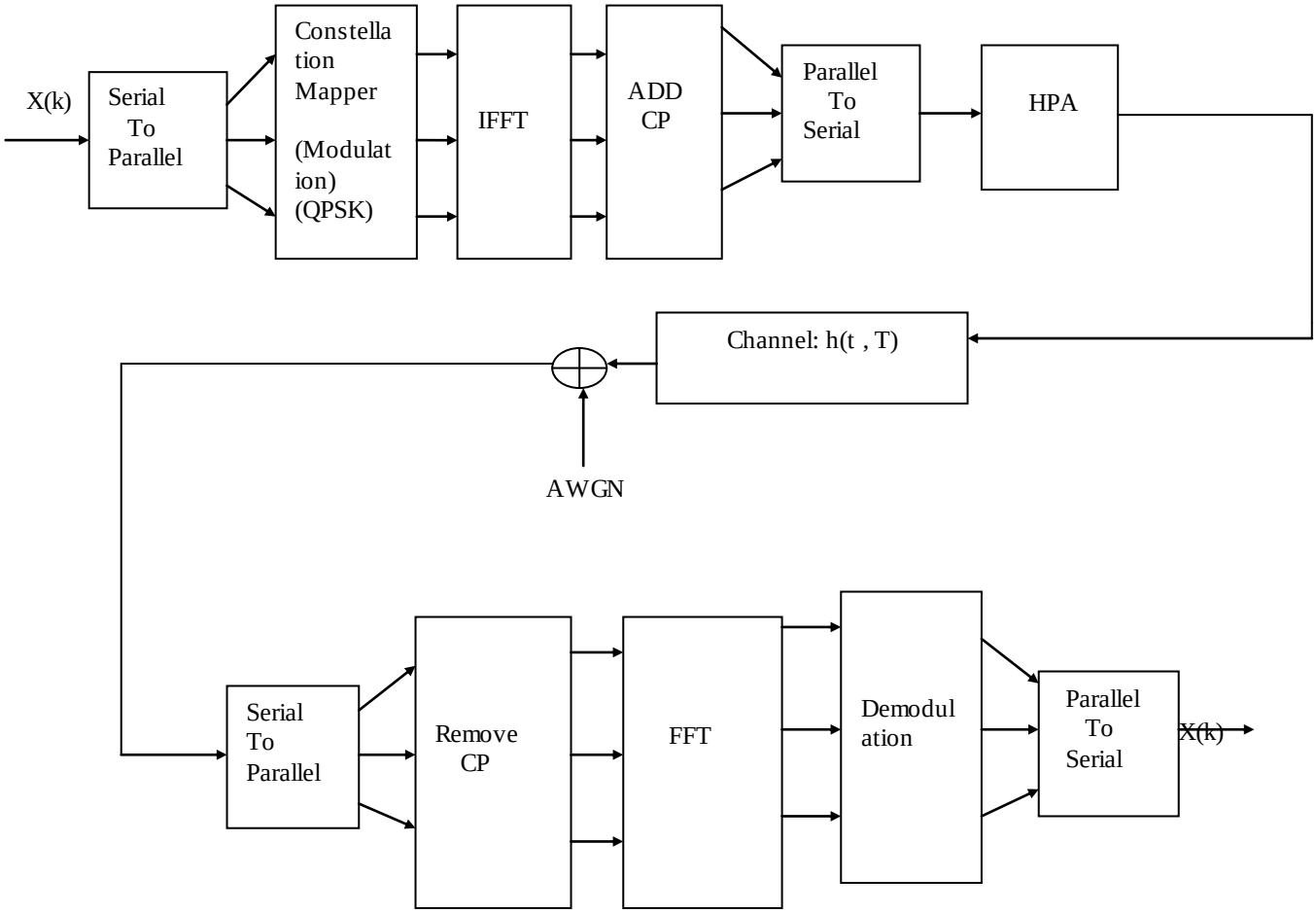


Fig.1.OFDM Transceiver

A continuous random data X(k) is generated serially from a random source as input to the OFDM system. A random source is a random digital data source which can generate a data of any size and any length. X(k) is fetched into serial to parallel converter, then the X(k) signal is converted into N number of parallel signals which is subjected to mapping. The signals are mapped or modulated using QPSK modulation technique. In QPSK modulation technique it uses four possible phases for the carriers with the same amplitude. Two bits are mapped as one symbol in QPSK.

An inverse FFT is computed on each set of symbols which in turn gives complex time domain samples. IFFT block produces orthogonality between the subcarriers. This will prevent against the interference between the sub channels and removes the possibility of inter carrier interference. Then cyclic prefix is added to these symbols, cyclic prefix is nothing but ¼ th of the symbol which is prefixed before it to prevent inter symbol interference. Then it is subjected to parallel to serial converter. Then the data is serially introduced into high power amplifier which boosts the signal and allows it to pass through the additive white Gaussian noise channel. It is a channel that does nothing but add a white Gaussian noise to the signal passing through it. Fading will be null in this kind of channel. The signal is then converted from serial to parallel using the serial to parallel converter. Cyclic prefix is removed and the signal is converted to frequency domain using FFT. Then the signal is demodulated using a demodulator. The retrieved signals are converted from parallel to serial and X(k) is obtained as the output in an OFDM system.

B. Major aspects in OFDM system

a. Cyclic Prefix

Cyclic prefix is defined as prefixing of the symbol with a repetition of its end. A guard interval is the time between the two symbols, cyclic prefix is copied into guard interval and the guard interval is transmitted followed by an OFDM symbol.

The cyclic prefix is used for the following two purposes:
As a guard interval it removes the chances of intersymbol interference with the previous symbol.
Since the end of the symbol is repeated there would be linear convolution which can be modeled as circular convolution and then converted into frequency domain using Discrete Fourier Transform (DFT).

b. Inter Carrier Interference (ICI)

Due to Doppler shifts, frequency and phase offsets causes loss in orthogonality of the subcarriers in OFDM system because of which there will be an interference which is known as Inter Carrier Interference.

c. Inter Symbol Interference (ISI)

In a signal when successive symbols interfere with each other, it is called as inter symbol interference. The ISI is a disadvantage as it causes noise and makes communication less reliable. ISI is normally seen in multipath propagation and it introduces error in the decision device at the receiver end.

By adding cyclic prefix in guard interval and producing orthogonality we can eliminate ICI and ISI and get an efficient output from an OFDM system.

III. PEAK TO AVERAGE POWER RATIO

In multi carrier systems, the main problem is they have great sensitivity towards non linear distortion. In this system in band and out of band interference are non linear distortions which degrade BER performance of the system and adjacent frequency bands are affected. At the transmitter end of the system, high power amplifier causes non linear distortion. Non linearity of amplifier is amplitude dependant, so the input signal's amplitude fluctuation is the main concern in the OFDM system.

PAPR is the ratio of the peak power to the average power of the signal. And it is derived for the Nyquist rate sampled version of continuous signal. The maximum sample which we give might have lesser amplitude peaks than that of continuous signal. This analysis underestimates the distribution of the PAPR. It can also be observed that the Gaussian distribution has infinite values but the maximum amplitude value of OFDM signal is N times the average carrier amplitude. So the approximation does not hold good which means the shape of the PAPR distribution does not follow Gaussian distribution procedure.

PAPR can be mathematically defined as:

$$PAPR = 10\ log \frac{\max|x(t)|^2}{\frac{|x(t)|^2}{N}}$$

IV. PAPR REDUCTION TECHNIQUES

A. Distortion Techniques

Distortion techniques are the most efficient PAPR reduction methods. They are the spectral growth scheme. In these methods, amplitude of large samples taken from the output of the IFFT is limited. So there is no need of any side information for this. Even after PAPR reduction it retains the data rate. Compared to distortion less techniques they have low complexities.

The main problem in distortion technique is distortion noise which in turn affects system error rate. By filtering spectral re-growth can be corrected. But this process will re-grow the peaks which were reduced, that is the PAPR can be reduced at the expense of spectral regrowth. The main distortion techniques are clipping, commanding and pulse windowing. In this paper we are concentrating on clipping technique to reduce PAPR.

Clipping

Clipping is a simplest distortion technique where peaks above certain threshold level are clipped back down to the threshold. Clipping can be mathematically given as

$$X(t) = -\gamma_0 \quad if\ X(t) < \gamma_0;$$

$$X(t) = x(t) \quad if -\gamma_0 \leq x(t) \leq \gamma_0$$

$$X(t) = \gamma_0 \quad if\ x(t) > 1$$

If the clipping is too hard then spectral growth will occur. Clipping introduces clipping noise in an OFDM signal which increases the error rate. Clipping noise leads to simple symbol error rate (SER).

The main aspects of clipping are:

Across all subcarriers the BER is not uniform. Some subcarriers have slightly worst performance.

As the number of subcarriers increase the distribution of clipping noise over more subcarriers improves the BER.

The Gaussian assumption only holds for hard clipping and the noise tends to have impulsive distribution.

Advantages of clipping:

1. It is simple and easy to implement.

2. It does not require any additional information, thereby it maintains same data rate.

Disadvantages of clipping:

1. Due to in band distortion the bit error rate performance of OFDM system is deteriorated.

2. Because of out of band radiation spectral efficiency is degraded.

Clipping is done to an OFDM signal by setting a threshold and clipping the peaks which are above that threshold level and these clipped signals can be retrieved back by performing error correction and error detection process but if clipping is done excessively, at the output the original signal cannot be retrieved back

Fig.2. SLM Block Diagram

B. Multiple signal representation or distortion less technique

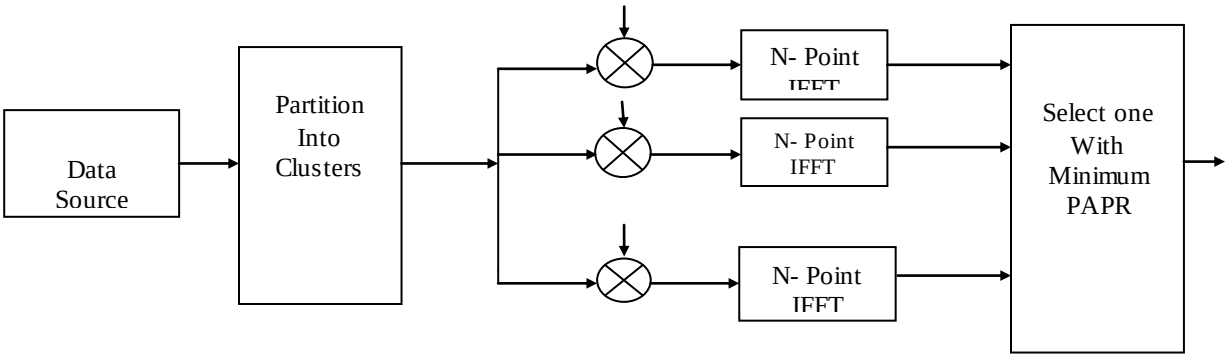
The basic principle of MSR is to obtain alternative transmit signals from the same data source. Many techniques are used to encode alternative transmit signals. These signals can be got in such a way that all signals have different PAPR properties and the signal which has lowest PAPR values is used for transmission. In this paper we propose a technique called Selective Mapping (SLM).

Selective Mapping

Selected Mapping (SLM) is signal scrambling technique used to reduce PAPR of OFDM signals. In this technique using specialized scrambling sequences input data has been scrambled. The sequence which produces lowest PAPR is used for transmission.

SLM takes advantage of the fact that PAPR of an OFDM signals is very sensitive to phase shifts in frequency domain data. Here, the input data sequence is converted from parallel to serial and each parallel sequence is multiplied by one of the phase sequences to generate alternative input symbol sequence. On each alternative input data sequence N-point IFFT operation is performed. A new independent phase adjusted OFDM frame represents the same transited information but have different PAPR values. Among these, the sequence that has the lowest PAPR is selected for transmission.

Block diagram of selective Mapping is as shown below



ADVANTAGES OF SLM TECHNIQUE

1. It reduces PAPR efficiently.

2. There is no any distortion generated.

Disadvantages of SLM technique

1. There is additional information generated which produces low PAPR which is required to be transmitted along with OFDM signal. This added information increases the overhead.
2. Problem of high computational complexity.

V. SIMULATION RESULTS AND DISCUSSION

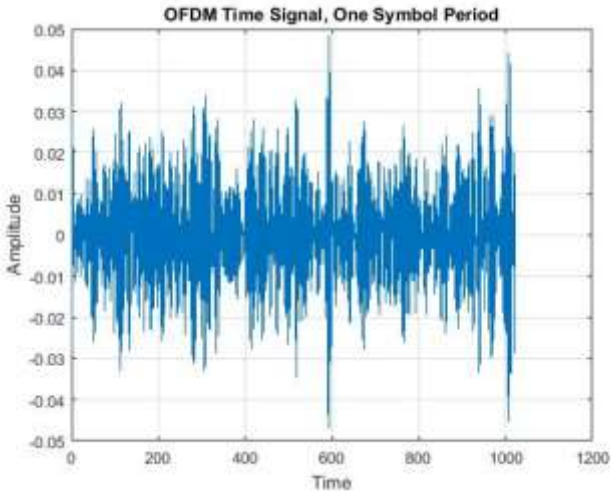


Fig.3. One symbol period of an OFDM time domain signal

The above waveform shows OFDM signal of one symbol obtained after the signal is computed by IFFT

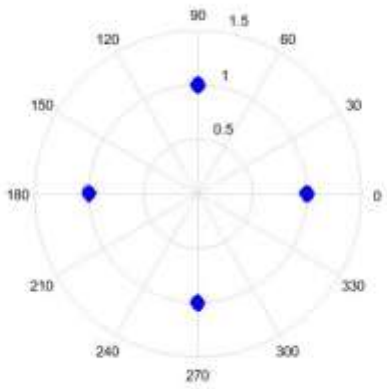


Fig.4. Phase constellation diagram

The above diagram is the constellation diagram of QPSK mapping which is used for modulation in the OFDM system.

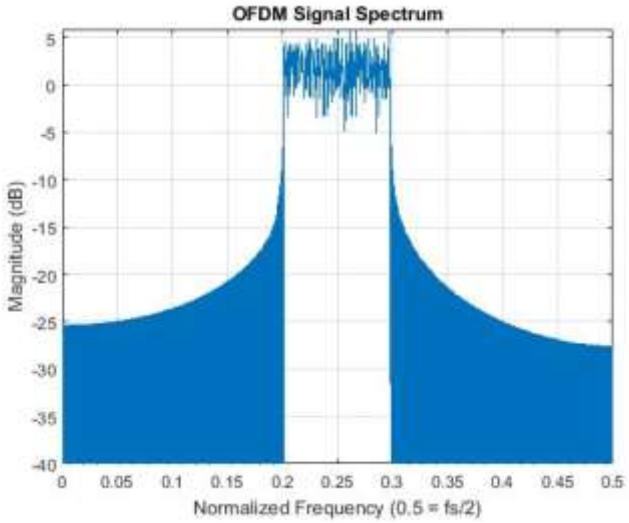


Fig.5. Normalized Power spectrum

The power spectrum obtained for the carrier count of 50, and the symbols per carrier is given as 10.

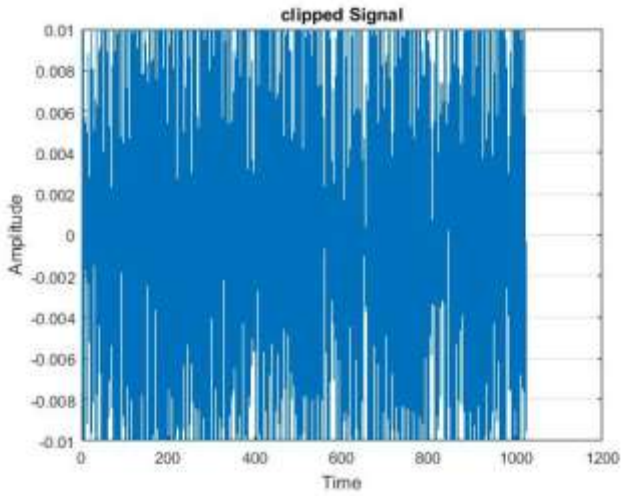


Fig.6. Clipped signal

The above figure shows the clipped signal

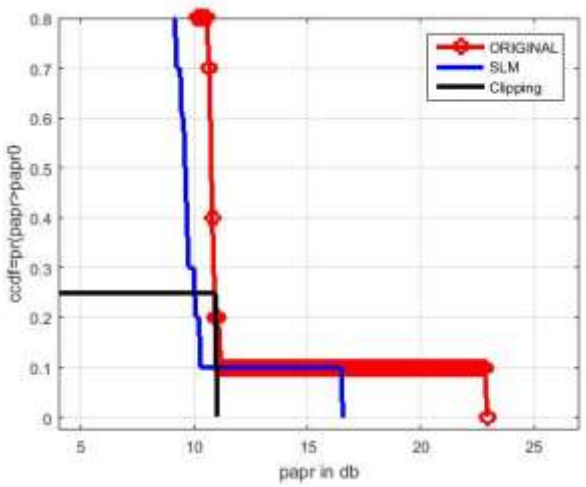


Fig.7. Comparison of all the PAPR

It is the comparative analysis of OFDM signal which is not subjected to any of the PAPR reducing techniques with the clipped and selectively mapped OFDM signal. By this graph we can see that in Clipping there will be PAPR reduction of 7dB and in SLM there will be PAPR reduction of 11dB from the original signal.

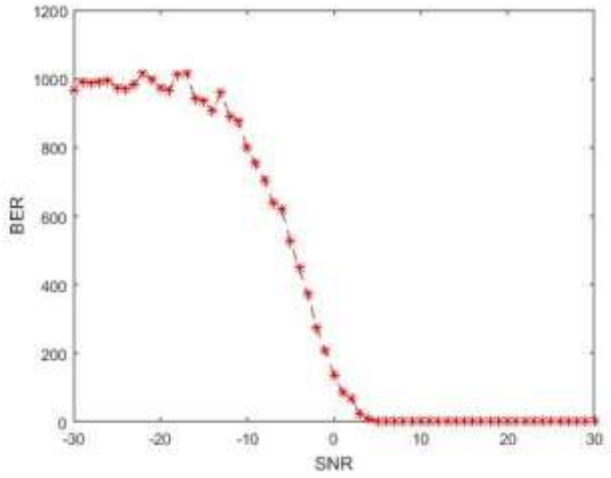


Fig.8. BER Plot

This is the bit error rate performance of signal to noise ratio from -30dB to 30dB, where the noise is more near -30dB and gradually decreases towards the 30dB and at 30dB there will be no noise so BER will be equal to zero at that instant.

VI. CONCLUSION

In this paper Clipping and SLM PAPR reduction techniques for multi-carrier transmission have been discussed. To reduce the PAPR these two techniques have been proposed and they possess all potential to provide substantial reduction In PAPR due to loss in data rate the transmit signal power increase in turn BER will also increase because of these two computational complexity increases. Comparative analysis has been made between these two techniques.

VII. REFERENCES

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